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CYBERNETICS APPLIED TO TEACHING RESEARCH

by Alfred Dietz

- East Germany -

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CYBERNETICS APPLIED TO TEACHING RESEARCH

- East Germany -

Following is a translation of an article by Alfred Dietz, in the German-language periodical Paedagogik (Pedagogics), No. 1, East Berlin, January 1963, pages 114-120.

The following is intended to furnish a small contribution to the attempts at interesting the research pedagogue in applying cybernetic considerations to his work (note: cf. "Cybernetics and Pedagogics" published in Paedagogik, No. 10, 1962, page 949).

Due to the general importance of cybernetics, it has become a necessity for all disciplines of the sciences to approach the aspects of cybernetics from the specific viewpoint of the individual field both psychologically and methodologically.

An understanding for the necessity for this approach will have been gained wherever the character and possibilities of cybernetics have become clear to a sufficient extent. Such understanding will moreover help in preventing extreme attitudes as represented by regarding cybernetic considerations as a temporary fad and by unwarrantedly extending the limits of possible application of cybernetics.

The general significance of cybernetics becomes especially clear when we briefly review some of the characteristic features of modern development in all fields of science where pronounced delimitation, differentiation and specialization in regard to the subject and methods of research and the systematization of findings has become typical. Another tendency is manifested at the same time which is the attempt at more inclusive viewpoints both within individual as well as in different disciplines. This tendency has necessarily risen out of the progressive understanding of reality in the individual fields of science. The more accurately reality is grasped and described by the different scientific disciplines, the more clearly is the general interrelation of reality manifested.

This encompassing understanding of the interrelation of reality is advanced to a very high degree through the development of cybernetics. It is becoming possible for the individual scientific fields to obtain a greater over-all view in the approach to research and new methodological conceptions. Only through cybernetic approaches are we successful in disclosing the analogous character of certain problems and problematics in subjectively different fields.

In his book Cybernetics and Philosophy, Georg Klaus characterizes the significance of cybernetics as follows: "The new science of cybernetics with all its social, scientific and philosophical consequences is, in addition to the scientific and technical domination of atomic energy and the start of spatial navigation, the most important scientific phenomenon of today. Cybernetics reaches far into our material and intellectual being. In regard to its revolutionary effect, it parallels the discoveries of men like Copernicus, Darwin and Marx (note: cf, George Klaus, Cybernetics and Philosophy, Dietz Verlag, Berlin, 1961, page 5.).

Obviously, pedagogy cannot remain unaffected by such a scientific development. Aside from the consequences for the content and structure of learning, particular attention must be directed to the possibilities of application of new scientific approaches and working methods.

In our remarks on the complex of questions raised here, we shall restrict ourselves to two problematic fields with special emphasis on research of teaching methods. We shall attempt first to apply certain cybernetic concepts and considerations to given factors of the teaching process. In addition to the possibility of understanding the research problems essential here in a wider relation, clarification of the intelligent application of cybernetic concepts creates the prerequisites for the applicability of cybernetic working methods in the fields of research of interest here. We shall also attempt to direct attention to the possible utilization and the necessary development of quantitative methods of cybernetic analysis to research on methods of teaching.

#### Concept and Content of Cybernetics

With Klaus, cybernetics can be defined as the "theory of the interrelation of possible self-regulating dynamic systems and their partial systems" (Note: idem, p. 2). Another equivalent explanation (cf. Sobolev in Voprosy Psichologii, No. 5, 1958) but stressing some special features states that "cybernetics is the science of the processes of transmission, processing and storage of information."

The character of cybernetics is interpreted erroneously by speaking of a "science of general relations." In the infinite multiplicity of all interrelations of reality, cybernetics is concerned with only one section, i.e., only one form of the interrelations, the exchange of information. This must be kept in mind, especially in applying cybernetic viewpoints to given problems.

It is already becoming clear that the confrontation of pedagogics and cybernetics cannot attempt to totally encompass relations of a pedagogic nature through cybernetic principles. Cybernetics is restricted to research on processes which take place in automatic control systems and here abstracts the generally valid in the respective concrete factors from certain viewpoints. The latter include the study of the so-called flow of information in automatic control systems and, in connection with this, the general characteristics of the structure of automatic control systems and the general rules for the processing of information and the utilization of machines in the latter.

In applying cybernetic concepts, special attention must be given to applying them in their clearly defined abstract significance. Much confusion can be created and lead to dead-end consequences, in particular to erroneous mechanistic adaptation, if cybernetic concepts are utilized in too narrow an interpretation of their developmentally conditioned origin as, for instance, the concept of information in view of its origin out of telecommunications or the concept of entropy in its physical significance.

The basic element of cybernetic systems is the so-called control and/or feedback loop. The principle of such a loop consists in the action of a certain number of causes on a system, the results of such action in the form of so-called informational data transmitted and processed by a so-called regulatory center into so-called instructional data which interact with the primary causes. This exchange and processing of information takes place in a self-regulating system as long as a certain stable state has not been achieved. It is also possible that an element exists in such a system which has the function of keeping and storing information.

The generally essential in automatic control systems investigated by cybernetics is found in many different concrete areas. For example, in the nervous system of man, centers exist which receive, process, convert and store information and transmit it for the control of other centers and of the paths for the flow of information. The realization of control processes in cybernetic machines has certain analogies with some functions of the human brain, e.g., in regard to memory and the processing of information. Human collectives can also be regarded as systems which receive, store, process and retransmit information (theory of communication).

All types of messages in the form of spoken or written words, electric impulses, nerve stimuli, etc. are designated as information. The processing of information in a conducting and in a controlling center consists in certain so-called elementary acts in which the reception of certain signals and the creation of certain other signals takes place. Information can be expressed, retransmitted and processed in different ways by signals. We speak of different methods of the so-called coding of information.

In the processing of information in an automatic control system, the total of all elementary acts and all logical factors which are examined during such processes are designated as the algorithm of the processing of the information. Quite generally, we understand by an algorithm the exact instructions, according to which a certain system of operations is to be carried out in a certain sequence and according to which all tasks of a given type can be solved. At this point, we should point out the special significance of the concept of algorithms also within the field of investigation of methods of teaching. It plays an essential role in the problematics of objective methods of teaching based on the recognition of the laws of interrelation.

It is an important task of cybernetics to analyse actual automatic control processes in view of the inherent laws of information processing. This makes it possible to obtain findings for the algorithmic description of automatic control processes examined which may form the basis of a mathematical model and consequently the realization by machines of certain automatic control processes. The investigation of the efficiency of algorithmic description of given factors in practice is the criterion whether the section of reality investigated has been examined accurately and completely in regard to its various effective components. The field of cybernetics in which transmission, processing and storage of information is investigated from the quantitative viewpoint is called theory of information. The theory of information is based in principle on the theory of probability. Especially significant is the introduction of a scale of information by means of the concept of quantity of information. This makes it possible to measure the quantity of information which is transmitted within unit time along certain paths. In general, such paths of transmission are called channels. Channels transmitting information may be media of different kinds such as circuits of metal, air, or nerves. These media possess the property of transmitting signals of a certain kind.

The quantity of information transmitted through certain channel systems within individual intervals of time is considered as the speed of transmission of information. In this sense, we also speak of the permeability of a channel. The reliability of transmission

of information is characterized by the probability of reception of non-mutilated information. Finally, by capacity of a channel system is understood the maximum speed of transmission of information in this channel system.

Pedagogic investigations attempting to disclose general laws in pedagogic processes, in teaching, for example, must logically start from the philosophical assumption that all processes in reality take place according to general laws, the process of teaching also, for example, and that the general laws of reality can be determined and therefore also the general laws in the process of teaching. Insight into the principle of interrelation of all processes of reality and into the dialectical character of this interrelation must be the basis of research because only then can pedagogic factors be understood and evaluated thoroughly.

This basic conception is of decisive significance for the following considerations: in the cybernetic approach is contained the dialectical approach to the comprehension of reality in a pronounced degree. In an examination of the teaching process so orientated, the concept of interaction (feed-back) plays an essential role. What is concerned here is in particular the interaction between teacher and pupil and the interrelation between this relation and different environmental factors.

The consideration of all essential factors interrelated in a given pedagogic system is extremely difficult but necessary if we want to be successful in penetrating sufficiently deeply into the dynamic of the process of teaching, to disclose the principles of the laws of interrelation, to describe these accurately both from qualitative and quantitative viewpoints and to base on them compelling instructions of action. In such a cybernetic illumination of the process of teaching, it is obviously impossible to totally encompass the structural relations of teacher, pupil and environmental factors. That such an attempt would be doomed to failure has already been made clear from the characterization of the tasks and limits of cybernetics.

From the point of view of cybernetics, we must first note that the reception, processing, storage and retransmission of information takes place in the actions of teaching and learning. In discussions between teacher and pupil, information is exchanged which is here represented by the signals of the spoken word. Essential channels of the channel system conducting the information are here the air and the auditory nerves. Further information is received by reading from a text book, from looking at a picture on the blackboard or from an educational aid. Here the optic nerves are an essential channel for the transmission of information.

During experiments in classrooms as well as by activities in practical production, other channel systems such as the nerve paths for tasting, smelling and feeling may become effective in the transmission of information.

The well known pedagogic principle of encouraging many-sided questions from the pupil to gain knowledge of a subject or object therefore also means to make use of the optimum number of channel systems in order to obtain a maximum of information. In the analysis of the application of certain methods of teaching in certain tasks of teaching, the question may be of importance which of the channel systems are more or less essential for obtaining specific subjective information.

The exchange of information between teacher and pupil in the classroom does not take place arbitrarily but is a control process. In our explanation of education and learning as a purposefully directed dynamic process effecting changes in knowledge and ability, the leading and controlling role of the teacher is included. This shows a certain analogy to the functions in self-regulating dynamic systems in the cybernetic meaning. For example, in the investigation of a factual situation, the pupil gains certain information on this factual situation. His statements on these informations or their processes are information data for the teacher who processes them according to certain principles of education and learning and converts them into instructions in the meaning of cybernetics. These instructions are made by him to react on the pupil and eventually on the factual situation under investigation in the form of measures of methodical teaching. With this, he intends to control the investigation of the pupil and his manner of processing observational information in direct application to a certain result of investigation. This process of the exchange of message and control information between teacher and pupil continues in regard to the factual situation concerned until the desired result of education or learning has been achieved.

The processing of the information data and their conversion into action and instructions takes place according to certain viewpoints of education and learning oriented on the respective object and situation and follows principles and rules of methodical teaching. Such a process has a close relation to the concept of algorithm: the elementary acts of information processing are based, in addition to the examination of the logical conditions, on a system of methodical teaching rules. Research on the methods of teaching attempts to objectively disengage from the investigation of the principles of the teaching process effective methods of teaching, i.e., to obtain rules of methodical action, the control application of which reliably permits the obtention of certain results of

education and learning in the optimum favorable manner. In this sense, it must be the objective of research on methods of teaching to arrive at an algorithmic description of the methodical solution of the different specific tasks of teaching.

In research on the teaching process so oriented, the investigation of the transmission, processing, storage and retransmission of information also plays a role. On the basis of the cybernetic viewpoint, there is offered a whole series of noteworthy questions and problems. In addition to the outlook already stressed, we should like to state the following bases of departure for further considerations: in analogy to the question of a suitable organization of information, it is here important to know which forms of the formulation of information are most suitable for specific objects or classes of objects, i.e., what forms can communicate the desired information most quickly and most reliably. This includes obviously also the question of visual aid or in general, the question of the optimum effective manner of expression for specific fields such as the utilization of speech, writing, pictures, gestures, and mimics.

Of further importance is the investigation of interference occurring in the reception, transmission, processing, storage and retransmission of information which may lead to alteration of the latter. Here external, individual and factual elements in the situation may be effective in teaching. If we investigate the kind and manner of processing of information, then the problem of analogous conversion of information is important. A special form of analogous conversion of information is the logical conversion by which these signals, which are the carriers of information, are converted according to general principles. This becomes particularly apparent in the solution of mathematical problems where we speak of an equivalent reformulation of mathematical expressions. In the theory of equations, the pupil is frequently required to carry out such conversions and, in their realization, it is necessary that a certain quantity of initial information exists, for example, knowledge of logical and algebraic rules.

In this connection, the problem of knowledge of the pupil can also be examined. The content of the memory should be understood as the storage of information. Notes and text books are also storages of information. In the storage, the information is kept in the form of signals. In learning, we know that it is of great importance that the duration of storage of information in the memory of the human being is a function of different internal and external factors of influence. These signals stored in the memory are subject to interference which may change or wipe out information.

We might also mention the possibility of utilizing certain theorems of the theory of information in methods of teaching. For example, the following statement on the theory of information may be of value perhaps in regard to the rate of progress in treating a subject taught: "the reliability and accuracy of transmission of information is dependent on sufficiently detailed formulation of such information." We had explained the permeability of a channel as the quantity of information transmitted within unit time by the channel. Here is the valid principle: "the reliability and quality of transmission decreases with the increase in speed of transmission. The speed of transmission of information by a given channel system has a maximum and when this is reached, there is no possibility of further increase." This maximum is called the capacity of the channel system and is the largest quantity of information which can be transmitted by the channel on the average within unit time.

In view of the laws effective in the process of teaching, the concept of interaction had been stressed as particularly important. To search for laws in the process of teaching means to comprehend the given principles of the interaction, inherent in the process of teaching, between the multiple effective factors of influence qualitatively and quantitatively as far as possible. The characterized relation between teacher, pupil and environment roughly encompasses this structure of relations.

It is certain that given fields of the dynamics of the process of teaching selected as subjects of research on teaching can be comprehended fully in their given principles, i.e., reflected true to reality, only if all decisive interrelations between the essential factors of action are fully comprehended. We have already pointed out that it is precisely this necessary complete consideration of all essential factors which is a problem difficult of solution for pedagogic research. When using simplifying assumptions in pedagogic research. When using simplifying assumptions in pedagogic investigations, we always expose ourselves to the risk of obtaining findings for whose practical application we must assume the validity of factors within the sense of these simplifications.

Let us assume for example that we wish to determine in the field of teaching mathematics what will be the effectiveness of a certain, accurately defined methodical procedure in developing the ability for analysing the mathematical structures contained in a given problem. The methodist engaged in research on dialectical principles will not expect a priori to be able to disclose a direct causal relation between the influence and the effectiveness of methods in the pupil. He will take into account that this control process directed toward the development of the ability mentioned consists in an interaction characterized by not being unidimensional.

On the contrary, he will keep in mind that the effect of his influence varies as a function of different factors which are again interrelated among each other. The degree of the existing ability of abstraction, the degree of the visual or artistic receptivity and the distribution of interest in the problem may, for example, be such factors in a given case.

The entire process therefore is manifested in a system of inter-relations. Each step-by-step stage in the development of the ability mentioned is not to be understood as the result or the direct consequence of individual measures of the teacher but as the result of the interaction taking place during the process and expressed in the methodical measures of the teacher and their interlinkage with the interaction between the teacher and the pupil and with other factors influencing the process. These can also be of an "external" nature like street noises, time of day of instruction, and so on.

It is also of essential significance in the analysis of a given principle in the field mentioned that we should not expect to obtain data on the functional relations in the mathematical sense of indisputable evaluation. The results of interaction are represented rather as a distribution of probability and their adherence to inherent principles as manifested by the fact that they permit scientific predictions in the form of statements of probability.

In view of the example indicated above, statements of the following form may occur: such and such a stage of development of the ability mentioned may be expected under such and such a degree of influence of the decisive effective factors with such and such a degree of probability. This makes possible precise descriptions of the structure of the process considered and, in particular, exact quantitative scales, e.g., for a scientifically founded comparison of different methods of teaching in regard to their optimum effectiveness. From such aspects of the research on method, the direct relation to cybernetic processes, especially those concerning the theories of quantity of information, is given.

As outlined in the above remarks, it is primarily necessary in research on teaching to apply the theory of multi-dimensional distribution of probability because only then can the dialectical relation of the structure of processes of teaching be comprehended sufficiently accurately from the scientific approach. The utilization of modern quantitative methods in research on methods of teaching is only in its first stages. It will be necessary first to arrive at an individual comprehension on the different possibilities of the exact quantitative research methodology. Some advances in this direction, for example, in some fields of cytology and professional pedagogics and, last but not least, the respective investigations of methods of teaching by Soviet pedagogues should be followed attentively.